Development of Amplifier with Pulse Shaper for High Rate MWPC

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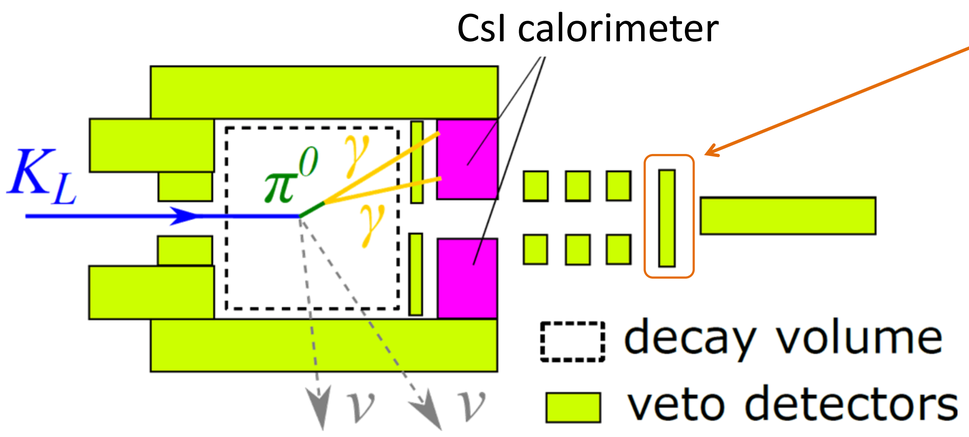
The KOTO Experiment

Search for $K_L \to \pi^0 \nu\bar{\nu}$

- suppressed in SM (BR ~ 2 x 10^{-11})
- small theoretical uncertainty (2%)

→ Sensitive to New Physics



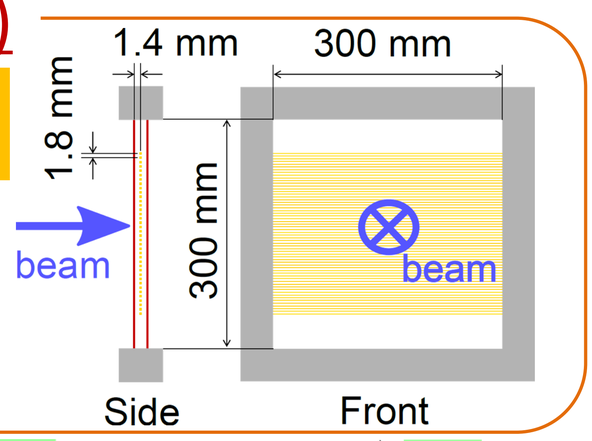
final state: "2γ + nothing"

Beam Hole Charged Veto(BHCV)

- Thin gap MWPC
  - low mass
  - high detection efficiency

for more details: Poster of K.Nakagiri

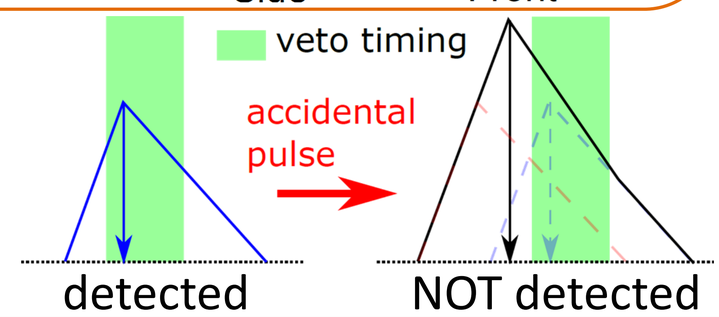
- high rate γ, n flux (~1 GHz)
- hit rate: 700 kHz/channel (max.)



pulse pile-up

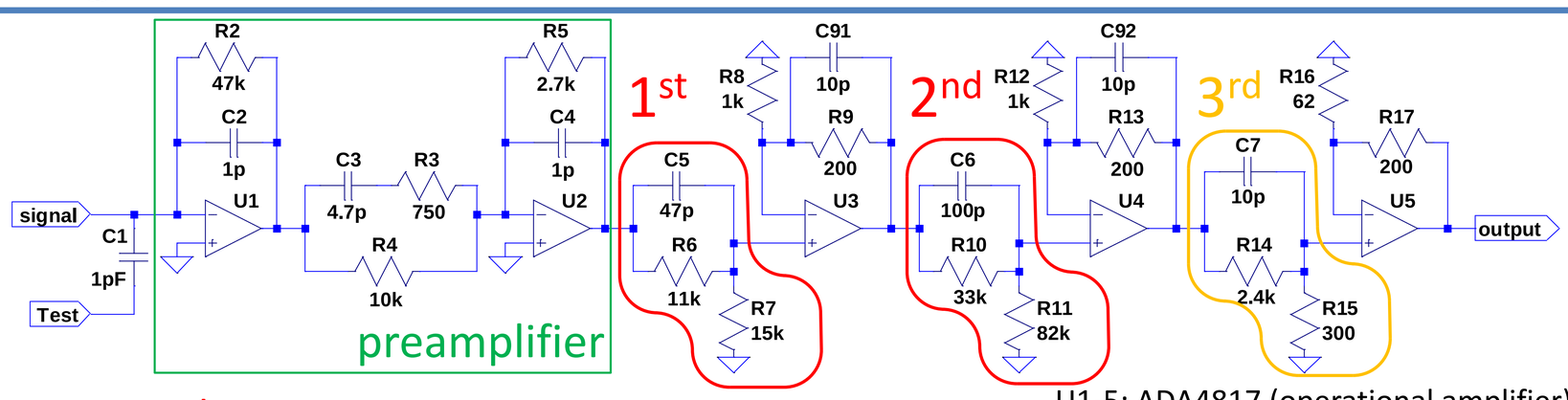
get wrong signal timing
due to accidental pulse

→ worse detection efficiency



SOLUTION: pulse shortening circuits (waveform shaper)
make an"exponential" waveform w/ short time constant

Design Technique: Three Successive Pole-Zero Cancellation



U1-5: ADA4817 (operational amplifier)

1st & 2nd pole-zero cancellation

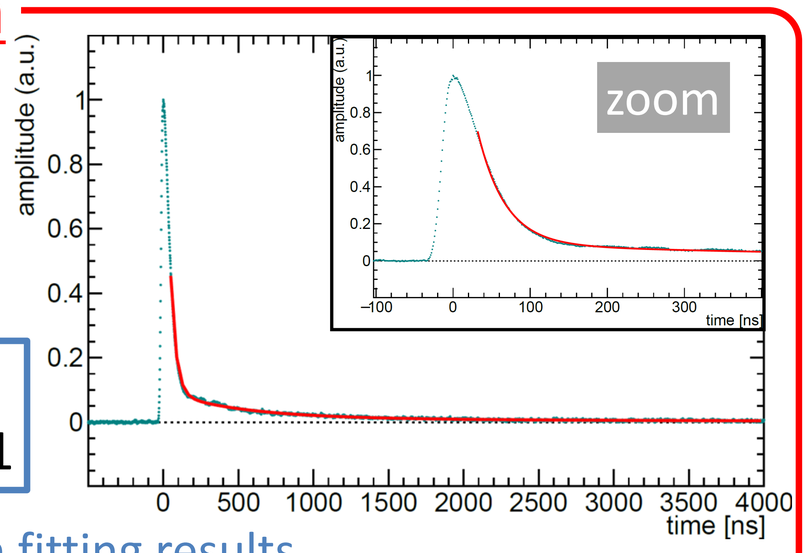
tail region of preamplifier output is approximated by three exponentials

$A\exp(-t/\tau_a) + B\exp(-t/\tau_b) + C\exp(-t/\tau_c)$

τ_b and τ_c can be removed by these

A = 1.493	τ_a = 35.4 ns
B = 0.0831	τ_b = 500 ns
C = 0.0131	τ_c = 3.4 μs

→ C5, R6, R7
C6, R10, R11

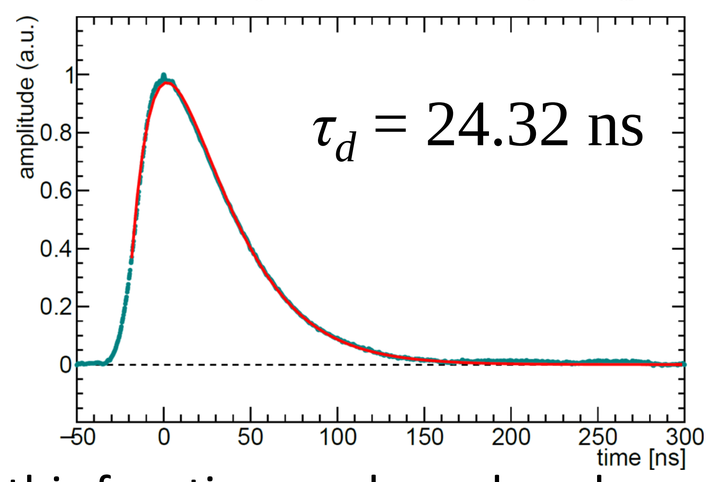


circuit parameters are determined from fitting results

3rd pole-zero cancellation

output of 2nd pole-zero cancellation

$D\,(t - t_0)\exp(-(t - t_0)/\tau_d)$



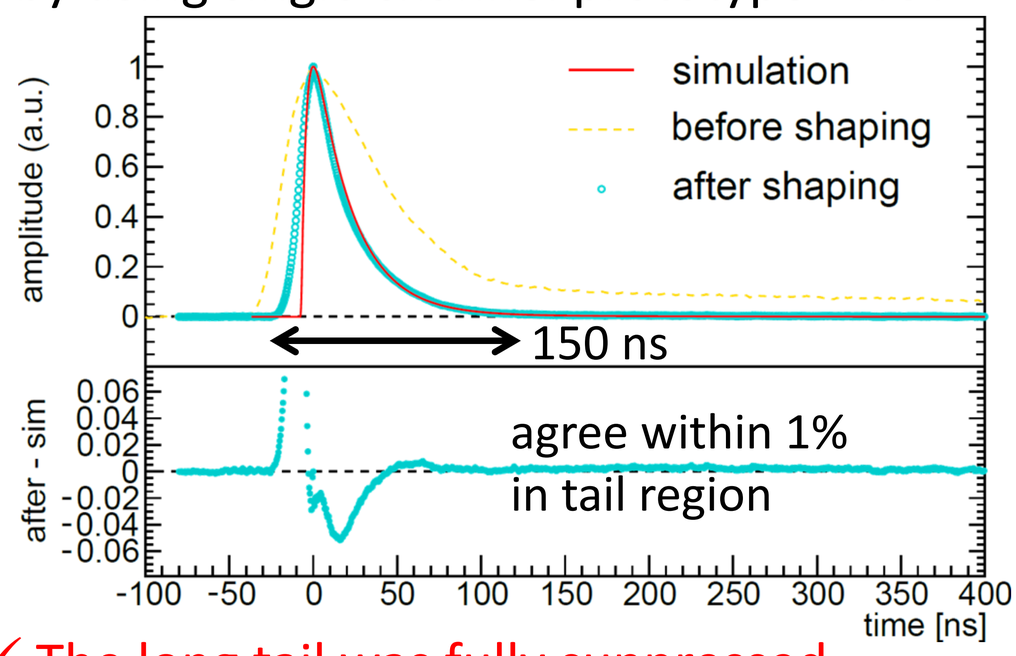
this function can be reduced
to a single exponential (τ = 24 ns)
by setting parameters as

C7 x R14 = τ_d
C7 x (R14+R15) = 3ns

* 3 ns is the time constant of preamp

Performance Test w/ Prototype

Performance of pulse shaper was checked
by using single channel prototype BHCV

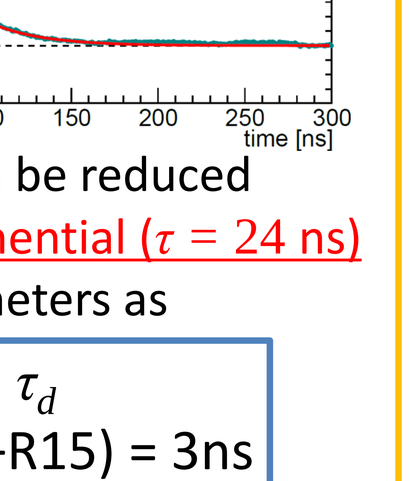


✓ The long tail was fully suppressed
✓ Waveform was almost the same as the design
→ pulse w/ time const. of 24 ns was achieved!

Development of Actual Amplifier

Using the same design as the prototype,
actual multi-channel amplifier have been developed
and started its operation in the KOTO experiment

output waveform by minimum ionizing particle



✓ The width was almost the same width of prototype
✓ Noise level was enough low for the operation of BHCV
→ The shapers well worked in the KOTO experiment!

Conclusion

- The amplifier with waveform shaper was developed for a high rate MWPC
- The circuit parameters were determined by fitting the waveforms to be processed
- The actual amplifiers have already developed and stated its operation in the KOTO Experiment